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EVALUATION OF CEREBRAL AND SYSTEMIC VASCULAR
DYNAMICS IN RESPONSE OF STRESS

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Prepared for:

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Evaluation of Cerebral and Systemic Vascular
Dynamics in Response to Stress

Final Report

Henry S. Miller, Jr., M. D.

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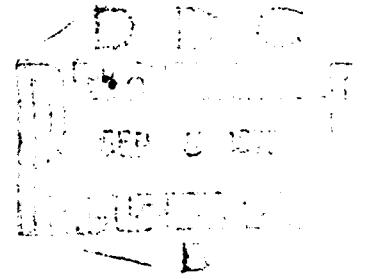
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13. ABSTRACT		
<p>This project was instituted in July, 1965 to investigate the vascular dynamics under stress conditions. We have developed and modified transducer techniques for obtaining direct and indirect measurements of the physiological variables under investigation and mathematical techniques for the computer analysis of this data. A 6 Channel recorder has been modified for 6 Channel electrocardiogram recording at rest and during active exercise. Atrial pacing, treadmill exercise and drug injections have been used as methods of stressing the cardiovascular system. The electrocardiogram, apexcardiogram, carotid pulse waves, phonocardiography and blood pressures have been done before and after exercise. In patients with known coronary artery disease, intra-arterial pressures, electrocardiogram, and clinical evidence of cerebral and coronary insufficiency are recorded during the stress by rapid atrial pacing. A comparison of atrial pacing and treadmill stressing is being made. Two groups of 20 subjects have undergone 20 weeks of exercise for physical conditioning, exercising 1 hour four days a week at 60-70% of maximum pre and post training. Treadmill stress and electrocardiogram, O₂ consumption and numerous chemistries were recorded. Physical conditioning increased tolerance, maximum oxygen consumption and recovery rate based on the return of pulse rate to normal. It is hoped to be able to predict the pulse rate and the degree of physical fatigue related to degradation in cardiac and cerebral performance and the effect that physical conditioning has on ones reaction to this type of stress.</p>		

SUMMARY:

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A 6 Channel recorder has been modified for 6 Channel electrocardiogram recording at rest and during active exercise. Atrial pacing, treadmill exercise and drug injections have been used as methods of stressing the cardiovascular system. The electrocardiogram, apexcardiogram, carotid pulse waves, phonocardiography and blood pressure have been done before and after various stresses. In patients with known coronary artery disease, intra-arterial pressures, electrocardiogram, and clinical evidence of cerebral and coronary insufficiency are recorded during the stress by rapid atrial pacing. A comparison of atrial pacing and treadmill stressing is being made.

Two groups of 20 subjects have undergone 20 weeks of exercise for physical conditioning, exercising one hour four days a week at 75% of maximum. Treadmill stress and electrocardiogram, O_2 consumption and numerous chemistries were recorded before and after conditioning. Physical conditioning increased tolerance, maximum oxygen consumption and recovery rate based on the return of pulse rate to normal. It is hoped to be able to predict the pulse rate and the degree of physical fatigue related to degradation in cardiac and cerebral performance and the effect that physical conditioning has on ones reaction to this type of stress. Project had to be terminated before these latter areas were investigated due to lack of funds.

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This project was started in July, 1965, with the objective of investigating vascular dynamics under stress conditions. Our purposes have been to measure the cerebral and systemic vascular data under baseline conditions and with physical and drug induced and psychological stresses. We have correlated intravascular findings with extravascular (indirect measurements), to develop indirect techniques that are known to reflect the changes in the cardiovascular system that occur with stress. In addition, we have evaluated several newly developed transducers, both for intravascular and extravascular measurements of the physiological variables, and have utilized available methods under different circumstances in the recording of the physiologic data. The final and probably most important portion of the project was to develop mathematical techniques for the computer analysis of the physiological data recorded.

During the initial two years of the grant period, most of our efforts were directed toward the development of various transducer systems that would adequately record changes in the cardiovascular dynamics that occur with stress. We experimented with several methods for automatic acquisition and analysis of the physiological variables and in the process have developed a very workable system for data handling. The types of transducers have changed from year to year depending on the equipment available and the type of stress employed in the study. As previously reported, the intravascular data is obtained during cardiovascular and cerebrovascular catheterization studies with simultaneous indirectly recorded data. The indirect cardiovascular data is largely recorded in a separate area within the Medical School equipped for phonocardiography and exercise testing. During the last few months of the previous granting period and throughout the eight-month period since August 31, we have been able to evaluate various cardiovascular phenomenon before and after maximal stress. Two groups of normal subjects have been evaluated before and after physical training.

As indicated in the last annual report, we have two groups of subjects consisting of 30 men each between the ages of 25-35 training in a walking/jogging type of exercise program. The amount of walking and jogging each subject did was determined by that amount necessary to produce a heart rate of greater than 75% of his maximum rate as determined by a maximum exercise stress test. The subjects were exercised thirty minutes, four days a week. These men had no known or detected cardiovascular problems. All individuals were stressed maximally by treadmill before and after 20 weeks of physical conditioning. Before and after each testing period, the serum electrolytes, cardiac enzymes, sugar and electrocardiograms were determined. Maximum oxygen uptake and determination of body fat were also measured. Physical conditioning was found to improve the exercise tolerance of the individuals by an increase of approximately one stage in the maximum stress, utilizing the Bruce Test. They improved their oxygen uptakes at maximum stress and rather markedly decreased their cardiac recovery time as determined by pulse rate. This averaged approximately 3.5 minutes less time for recovery to a similar pulse level comparing the pre and post physical conditioning stress tests. There was no change in the serum sodium, potassium or chloride when compared before and after exercise session. The CO₂ did decrease appreciably after maximum stress. The serum enzymes were not measured, as has been done in other studies, as we were not interested in those changes at this time. Our primary concern was with sodium and potassium changes specifically to see if changes in these electrolytes were correlated with ischemic changes in the electrocardiogram.

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After completion of this study, a second group was evaluated, consisting of 20 men between the ages of 39 and 55 who had no detectable heart disease. This group was trained with a rapid walking type of exercise one hour four days each week for a period of 20 weeks.

In testing all these people at the 20-week level, we found that all had increased exercise tolerance, increased oxygen consumption and decreased in recovery periods as noted in the younger group with more strenuous exercise. This latter group is being compared with 9 subjects, age matched and not trained, who have had the stress testing and oxygen consumption determination with the exercise group and again after 20 weeks to see whether experience on the treadmill accounts for any of the improvement noted. The results in all parameters were essentially the same. Of interest, 30% of the "normal" men trained had positive ECG stress tests following the training period when stressed to maximum. All the subjects exceeded the original maximum by 20-30%. None had ST segment changes at the initial stress test level.

Initially, our stress testing is done with an ECG monitored treadmill system utilizing a routine electrocardiographic machine with the 5 lead type of exercise monitoring cable. This allowed rapid recording of all standard and augmented limb leads plus one chest lead which was placed in the V₄ position. There was continuous monitoring of the V₄ lead by oscilloscope with a strip recording of V₄ made every minute during each exercise period. At the end of each three minute mark, the patient had leads 2, 3, AVL, AVF, and V₄ recorded in rapid succession while the treadmill was being adjusted for the next exercise level. An immediate 2 minute, 6 minute recording of these leads were made with the patient in the supine position following maximum exercise.

With the acquisition of a 6 channel Siemens Minograph Cardirex adapted for exercise electrocardiography utilizing Leads 2, 3, AVL, AVF, V₂ and V₅, we were able to record the electrocardiogram before, during and after exercise as well as a phonocardiogram and carotid pulse waves before and after exercise with the same instrument. This instrument was a high frequency response up to 600 cycles per second which added little to the interpretation of the electrocardiogram but was quite important in the phonocardiogram to more clearly delineate the various heart sounds and murmurs. The phonocardiograms, carotid pulse waves, and a Lead 2 of the electrocardiogram were recorded simultaneously before and after exercise in many of the patients. The high-frequency characteristics of the recorder were quite important in determining the exact point of the onset of the QRS, the components of the first sound, and to more accurately divide the components of the second sound. With the carotid pulse wave, we were able to do systolic time intervals and note the changes with exercise more accurately.

With the utilization of this recorder, we have been able to move into our latest phase of pre and post stress evaluation, that being recording of the apexcardiogram, heart sounds, and carotid pulse waves in addition to the electrocardiograms. To date, insufficiency data is available to draw any conclusions. However, these studies are to be utilized on the future training groups before and after conditioning. The details of the training programs were presented in the new grant continuation request.

We have continued to compare the various intravascular and extravascular measurements made during cardiac catheterization studies. During the past year,

a catheter tip electromagnetic flow meter has been utilized in the animal research lab. It has now been made on a catheter sufficiently small to be utilized in peripheral and pulmonary arterial flow studies and is ready for our utilization in the catheterization lab. We reported experience with a catheter tip thermocoupled developed by Dr. Khalil which was used in several patients. This proved to be a very easily applicable technique with extremely reproducible results. This equipment has not been available to us since September 1968 when Dr. Khalil left the U.S. Naval Aerospace Institute in Pensicola, Florida.

The cerebrovascular research laboratory has now been in operation for 20 months, and we have continued to work with patients undergoing studies for problems with cerebral blood flow. We have had an opportunity to measure carotid artery pressures as well as the anatomic observation of flow through the obstructive lesions and the relative filling of each intracranial area by angiocardiology. Recently, an isotopic method for determining cerebral circulatory dynamics, utilizing a Gamma camera, has enabled us to study the speed and distribution of isotopic appearance in various areas of the brain as well as the time required for isotopic washout. By the nature of our studies we can compare intra-arterial, intravenous, and inhalation of isotopes as a means of studying the cerebral blood flow.

Right atrial pacing as a means of producing tachycardia has been employed in stressing a number of patients undergoing coronary arteriography producing the same heart rate as noted on treadmill exercise when the patient develops angina or has to stop with fatigue. The effect of this on the electrocardiogram, intra-arterial and venous pressure, as well as any cardiac or cerebral symptoms have been observed. We feel this is an excellent method to determine the problems associated with tachycardia and at what heart rate the performance of the heart and central nervous system may be reduced. However, as observed by others, it does not reproduce the catechol response and associated changes noted when physical exertion is used to attain the same heart rate. This will be quite valuable when only the heart rate can be determined.

The last two years have been far more productive in the true evaluation of stress on the cardiovascular system and this past eight months has allowed a number of new interventions in recording techniques as well as additional parameters that can now be recorded before and after stress. Our working affiliation with the Department of Physical Education and particularly with the close association with Dr. Michael Pollock, we are able to continue to evaluate the affect of physical conditioning on the cardiovascular changes produced by stress. A study which will specifically measure the effect of 45 minutes of training two days a week at 55-70% and 85% of maximal capacity will allow us to precisely determine the degree of exercise necessary for conditioning. Utilizing 15 men in each group and 15 age matched men who will serve as a control, we should be able to tell whether this amount of time, which the busy military man can easily fit into his schedule has any true benefit.

The majority of the information was reviewed in the last annual report. As funding stopped with this year and no project completion funds were granted, all projects had to terminate. A few projects will hopefully be financed from other sources. We were not able to return the proposal necessary.

We sincerely appreciate the generosity of the Department of the Army for the support of our project from 1965 to 1969. Our association with the men in other areas of resurach sponsored by the Army has been most rewarding. A

sincere apology for the delay,

ADDENDUM: We are enclosing the annual Report dated May 1969. The other annual reports were written by Dr. Robert E. Robinson and have apparently been taken with him to California.

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GLOSSARY:

BRUCE TEST

A graded type of treadmill exercise test with a gradual increase in speed of treadmill and degree of incline designed as a reproducible way to test an individual's physical endurance.

GAMMA CAMERA

Radioisotopic imaging device to picture isotopic presence rapidly without scanning.

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